CONSUMER AND SHEAR FORCE EVALUATION OF STEAKS FROM THE

M. SERRATUS VENTRALIS

A Thesis

by

JASON LEE BAGLEY

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2006

Major Subject: Animal Science

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Approved by:

Chair of Committee,	Jeffrey W. Savell
Committee Members,	Jimmy T. Keeton
	Joe D. Townsend
Head of Department,	Gary R. Acuff

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ABSTRACT

Consumer and Shear Force Evaluation of Steaks from the *M. Serratus ventralis.*

(December 2006)

Jason Lee Bagley, B.S., Texas A&M University

Chair of Advisory Committee: Dr. Jeffrey W. Savell

An in-home evaluation of steaks from the *M. Serratus ventralis* was conducted to determine consumer acceptance. Steaks were also evaluated by Warner-Bratzler shear force (WBS) evaluations. Steaks from the *M. Serratus ventralis* were either blade tenderized, injected with a salt, phosphate, and papain solution, or served as a control. Consumers (n = 136) were not given a specific method of cookery, but were asked to document cooking method and degree of doneness, overall-like, tenderness desirability, tenderness of cut, juiciness desirability, juiciness of cut, flavor desirability, and flavor intensity. When cooked on the grill, in the oven, or in a skillet, injected steaks received the highest ($P < 0.05$) ratings for tenderness. Furthermore, consumers rated injected and blade tenderized steaks higher ($P<0.05$) for overall like when they were cooked on the grill to a higher degree of doneness. Oven cooked steaks that were injected, rated higher ($P<0.05$) than blade tenderized steaks for juiciness. When cooked on the grill, juiciness ratings were also higher ($P<0.05$) for injected steaks compared to control steaks. Moreover, injected steaks had significantly lower ($P<0.05$) WBS values when compared to blade tenderized and control steaks. Overall, ratings for all steaks were adequate, confirming the *M. Serratus ventralis* as a potential high quality steak for use in the retail market.

DEDICATION

This paper is dedicated to my parents, Bill and Cindy. Through their constant love and support I found that all things are possible.

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This project was funded, in part, by beef and veal producers and importers through their $1-per-head checkoff, and was produced for the Cattleman's Beef Board and state beef councils by the National Cattleman's Beef Association.

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CHAPTER I

INTRODUCTION AND REVIEW OF LITERATURE

As with any business, the meat industry is evolving to meet consumer's demands. Consumers have moved away from the traditional large multi-muscled roasts, and are looking for smaller, more convenient cuts of meat. Meat processing plants have begun recently to fabricate carcasses to remove whole muscles, or pieces of muscles for use as individual retail cuts as opposed to multi-muscled cuts. To optimize value, processors are interested in identifying underutilized muscles to sell as steaks and roasts. Because middle meats have a well-established market share, innovative fabrication is occurring primarily in the chuck and round. Alternative fabrication is not only increasing carcass value, but more importantly, consumers are enjoying more affordable, high quality beef cuts.

With traditional cutting techniques, retail cuts are composed of several muscles often varying greatly in tenderness. In alternative fabrication styles, these whole muscles are identified and separated based on perceived palatability attributes. Belew, Brooks, McKenna, and Savell (2003) identified muscles from the chuck and round perceived to less tender which are most often ground to increase their marketability. Although these cuts may seem more marketable using this option, they are actually missing out on the revenue generated by selling them as steaks and roasts.

This thesis follows the style of *Meat Science*.

1.1 Tenderness

Palatability is defined as the interaction between several factors including tenderness, juiciness, and flavor. Boleman et al. (1997) and Savell and Shackelford (1992) found that tenderness was the primary economic factor for beef palatability. Furthermore, Boleman et al. (1997) revealed not only could consumers differentiate between tenderness groups, they also were willing to pay a premium for tender product. In Boleman et al. (1997), consumers were allowed to purchase steaks that had been placed in a predetermined category of tenderness according to WBS force (WBS) values. These researchers found that 96.4% of consumers bought steaks from the "tender" category (WBS force values of 2.27 to 3.58 kg). In addition, steaks from the "tender" category were given the highest ratings for juiciness, flavor, tenderness, and overall satisfaction. A more recent study on consumer acceptability of chuck muscles found that consumers would be willing to pay more for tender steaks and steaks that met their expectations for flavor (Kukowski, Maddock, Wulf, Fausti, & Taylor, 2005). Consumers seemed to be more concerned with palatability of chuck steaks rather than their appearance. Kukowski et al. (2005) also suggested that by using certain muscles from the chuck as steaks, instead of roasts, there could be greater value added to the entire beef carcass. Huffman, Miller, Hoover, Wu, Brittin, and Ramsey (1996) conducted a study where consumers rated muscles at home and in a foodservice establishment. Huffman et al. (1996) found that when asked about quality traits, 51% of participants ranked tenderness as the number one trait for quality, 39% of participants chose flavor as number one, and 10% of participants preferred juiciness as their most important quality trait.

The National Beef Tenderness Survey (Morgan et al., 1991) observed that a high percentage of retail cuts from the chuck and round received overall tenderness ratings less than "slightly tender," based on shear force values. Morgan et al. (1991) also reported that continued work was needed to improve the tenderness of retail cuts from the chuck and round if the beef industry were to accomplish an overall acceptable tenderness rating. More recently, the National Beef Tenderness Survey – 1998 (Brooks et al., 2000) stated that all steaks evaluated were highly rated by consumers. As reported, this was expected due to the highly desirable and low WBS force values observed for steaks from the chuck, rib, and loin. Brooks et al. (2000) found that steaks from the round still had the highest WBS force values of steaks evaluated compared with the chuck, rib, and loin. These benchmarking studies show that beef tenderness has improved. Researchers are now faced with the challenge of finding cuts of meat from the underutilized chuck and round that actually could be used for retail cuts.

1.2 Muscle Characterization

Much research has been conducted recently to characterize and identify those muscles from the chuck and round that have sufficient palatability to be used as retail cuts. Belew et al. (2003) categorized muscles throughout the carcass by their WBS force values. Included in the chuck muscles identified as "very tender" (WBS <3.2 kg) were the *M. Infraspinatus, M. Serratus ventralis*, and the *M. Biceps brachii*. Those designated as “tender” (3.2 kg < WBS <3.9 kg) were the *M. Teres major, M. Rhomboideus, M. Subscapularis*, and *M. Triceps brachii*. Remarkably, based on WBS, several muscles from the chuck have proven to be sufficiently tender for use as retail cuts. Reuter, Wulf, and Maddock (2002) defined intramuscular tenderness variation in round muscles with WBS force values, and found tenderness to vary depending upon measurement location within each muscle. Results indicate WBS values vary depending upon location within each muscle. Reuter et al. (2002) concluded that even muscles with low WBS values may still be variable in tenderness.

To counteract unpredictable tenderness in muscles across species, the meat industry has adopted several postmortem tenderization treatments. These treatments, when used on muscles destined for retail cuts, can help meet consumer demand for a tender product. Two of the most widely used methods of postmortem tenderization are blade tenderization and injection with a salt and phosphate solution.

1.3 Blade Tenderization

Numerous studies, by Savell, Smith, and Carpenter (1977), Glover, Forrest, Johnson, Bramblett, and Judge (1977), Mandigo and Olson (1982), Tatum, Smith, and Carpenter (1978), and Jeremiah, Gibson, and Cunningham (1999) found that blade tenderization improved beef tenderness. Savell et al. (1977) reported this tenderization method to improve beef tenderness without detrimental effects on other organoleptic characteristics or weight loss of the product. Davis, Smith, and Carpenter (1977) also reported blade tenderization to increase tenderness more than aging alone, without negatively affecting palatability.

According to some research there is no advantage from a second pass through a mechanical tenderizer (Bowling et al., 1975), thus one pass through a needle tenderizer is the accepted norm. However, Savell et al. (1977) observed tenderizing a total of three times reduced shear force values. Additionally, Savell et al. (1977) reported that blade tenderized cuts from light weight US Good (now graded US Select) carcasses, were equivalent to cuts from heavy Good and heavy Choice carcasses in tenderness, juiciness, cooking loss and overall palatability. On the contrary, Davis et al. (1977) found that needle tenderized cuts, when stored aerobically, had decreased retail case-life. Furthermore, it was recommended that subprimal cuts be tenderized after storage to minimize weight loss from purge. During tenderization, needles rupture muscle fibers, causing the release of water, which appears as purge during storage. Mandigo and Olson (1982) observed no differences in cooked or thaw loss percentage due to mechanical tenderization or blade size. This study also recommended a blade size of 3.2 mm to increase tenderness and provide sufficient strength to prevent bent needles. Blade tenderization is currently one of the most effective technologies for reducing variation in tenderness in the meat industry.

1.4 Injection

Injection of a salt and phosphate solution is commonly used across many species in the meat industry. The poultry and pork industries regularly use combinations of water, sodium chloride, and sodium tripolyphosphate to enhance tenderness, juiciness, and flavor of their products. This injection of ingredients has been reported by many to increase palatability. Vote et al. (2000), Robbins, Jensen, Ryan, Homco-Ryan, McKeith, and Brewer (2003), and McGee, Henry, Brooks, Ray, and Morgan (2003) all reported improved beef sensory tenderness and juiciness due to injection of these ingredients. More specifically, Vote et al. (2000) reported that with improved tenderness, juiciness, and cooked beef flavor, the injection (phosphate/lactate/chloride) was especially effective for maintaining tenderness of strip loin steaks cooked to a higher final internal temperature. McGee et al. (2003) demonstrated that injection of a solution of sodium chloride, sodium tripolyphosphate, and sodium lactate not only enhanced sensory panel characteristics, but also decreased WBS values and reduced cooking loss. Baublits, Pohlman, Brown, Yancey, and Johnson (2006) found steaks treated with sodium tripolyphosphate, and 0.5%, 1.0%, or 1.5% sodium chloride were rated more tender than untreated or sodium tripolyphosphate-only steaks. When injected with salt only, Hoffman (2006) reported that samples treated with salt were juicier and more tender when compared to samples not treated with salt. Furthermore, enhanced samples did not have higher purge or cooking loss. Looking at tenderness alone, Pietrasik and Shand (2005) found that brine injection into the *M. Semimembranosus* helped to improve yield and had the largest effect on tenderness when compared to non-injected beef, blade tenderization, and injection followed by tumbling.

Kolle, McKenna, and Savell (2004) compared several methods to increase tenderness of beef rounds. In this study, nine muscles from the round were treated with different tenderization techniques and cooked using either dry heat or moist heat. Muscles were placed into tenderness categories based on the work of Belew et al. (2003). Using dry heat cookery, the injection treatment was the most effective and enabled five muscles to be as "very tender" and three muscles classified as "tender." Enzymatic tenderization (Bromelain) resulted in two muscles categorized as "very tender," and two muscles as "tender." Using an in-home study to evaluate cooking method, degree of doneness, and palatability, Mueller, King, Baird, McKenna, Osburn, and Savell (2006) compared the *M. Semimembranosus, M. Adductor*, *M. Rectus femoris*, and *M. Vastus lateralis*. Muscles were separated and treated with either a control, blade tenderization, or injection with a salt and phosphate solution (12%). Mueller et al. (2006) reported that injecting round muscles with a salt and phosphate solution improved most palatability traits as compared to those that were blade tenderized. They also observed that cooking method and degree of doneness had little influence on consumer palatability, and differences were muscle specific (Mueller et al., 2006). Molina, Johnson, West, and Gwartney (2005) also conducted a study with chuck muscles and reported that the *M. Serratus ventralis* and the *M. Triceps brachii* showed improved tenderness when injected with a solution of sodium chloride and sodium tripolyphosphate. Furthermore, these added ingredients decreased the amount of detectable connective tissue in the *M. Serratus ventralis* when assessed by a trained sensory panel.

Along with salt and phosphate, a solution containing natural plant enzymes can be injected to increase tenderization. Tenderization of meat with plant proteases has been practiced for many centuries (Caygill, 1979). The most commonly used plant proteases are papain from papaya, bromelin from pineapples, and ficin from figs. When cooking treated meat, these enzymes become active at 50°C to 60°C (Foegeding & Larick, 1986) and increase in activity up to 80°C, but are subsequently denatured at higher temperatures (Caygill, 1979). The use of these plant enzymes to tenderize meat involves breakdown of connective tissue and/or muscle proteins (Caygill, 1979). Because these enzymes have the capability to breakdown both connective tissue and muscle proteins, there is a risk of over-tenderizing meat, resulting in an unwanted "mushy" texture.

Although blade tenderization and injection with a salt/phosphate solution can increase tenderness greatly, negative effects also have been reported. Vote et al. (2000) reported that with a phosphate-only treatment, consumer panelists tended to detect soapy and sour flavors. Baublits et al. (2006) on the other hand observed that diminishing color result from increased salt levels. As salt levels are increase, there is the likelihood of a saltier and perhaps less palatable product. In addition, increased purge loss and dryness after cooking have been described with blade tenderized steaks (Glover et al., 1977).

With these negative attributes aside, it is evident that some type of postmortem tenderization technique should be used to decrease the variability in beef tenderness. More specifically, these tenderization techniques should be used to increase palatability and marketability of underutilized cuts from the chuck. By focusing on enhancing the palatability attributes of these cuts, consumer satisfaction of beef could increase. While tenderness is ranked as the most important factor in palatability, other attributes such as juiciness and flavor cannot be diminished. Otherwise, the work put into tenderization, whether mechanical or enzymatic will be negated.

1.5 Cooking Method

Under laboratory research conditions, steak palatability is more easily tested because all factors, including degree of doneness and cooking method, are strictly controlled. Unfortunately, when steaks are cooked in the home, many of these factors may not be controlled. Consumer controlled factors such as cooking method and degree of doneness can have a great impact on consumer satisfaction (Lorenzen et al., 1999; Neely et al., 1999; Savell et al., 1999). It was reported by Goodson et al. (2002) and Behrends et al. (2005) that grilling was the preferred method for cooking steaks by consumers. It is important to identify which underutilized cuts tolerate this type of high-temperature, dry-heat cooking method. Some cuts may need a moist-heat cooking method to help solubilize the collagens in connective tissue. If cooked improperly, cuts can drastically decrease in palatability. Because degree of doneness is determined by the consumer, processors and retailers should use tenderization methods to decrease the variation in tenderness between degrees of doneness. Retailers must also make a conscious effort to market retail cuts and provide appropriate cooking instructions.

1.6 M. Serratus ventralis

To optimize profits, processors and retailers must begin to utilize lesser known muscles from the chuck. One of the most underutilized muscles from the chuck is the *M. Serratus ventralis*. Pfeiffer, Voges, King, Griffin, and Savell (2005), removed the *M. Serratus ventralis* was using an innovative fabrication style and found that it accounted for over 4.5% of the beef forequarter yield. This muscle, which extends over the chuck, rib, and plate primals, was documented as the sixth most tender muscle in the beef carcass with a WBS of 3.00 kg (Belew et al., 2003). As indicated by Johnson, Chen, Muller, Costello, Romans, and Jones (1988), the *M. Serratus ventralis* is the largest muscle from the beef forequarter, representing 8.9%. Pfeiffer et al. (2005) used the *M. Serratus ventralis* to yield 45.39% flanken style steaks, 15.90% serratus steaks and 34.30% lean trimmings. These cuts were similar to the IMPS #123D Beef Short Ribs, Boneless, the flat iron steak from the *M. Infraspinatus*, and IMPS #138 Beef trimmings, respectively. This accounts for greater than 60% steak yield and over 95% saleable yield. By realizing the merchandising opportunities for the *M. Serratus ventralis*, processors could add considerable value to the beef carcass. Moreover, retailers could provide consumers with a high quality, modestly priced steak from the chuck.

CHAPTER II

MATERIALS AND METHODS

2.1 Processing

USDA Select, arm chucks (n=87) were purchased from two commercial processing facilities and shipped to the Rosenthal Meat Science and Technology Center via refrigerated truck. Arm chucks were hung by the foreshank to prepare for fabrication 10 to 14 days postmortem. Shoulder clods (IMPS # 114) were removed, including the *M. Triceps brachii, M. Infraspinatis,* and the *M. Teres major*. The scapula was removed with the *M. Supraspinatus* (mock tender). The *M. Latissimus dorsi* and *M. Trapezius* were removed, exposing the *M. Serratus ventralis thoracis*. The *M. Serratus ventralis thoracis*, or thick portion, was removed completely from the arm chuck to ensure that the whole muscle remained intact. It then was trimmed practically free of fat and connective tissue. After fabrication, *M. Serratus ventralis* were randomly separated into one of three treatment groups. The three treatments included control, blade tenderization, and injection, with a solution of salt, phosphate, and papain.

2.2 Tenderization Treatments

Before applying tenderization treatments to the muscle, temperature, pH (pH Star, SFK Technologies, Cedar Rapids, IA and Model IQ150, IQ Scientific Instruments, Inc., Carlsbad, CA, with model pH17-SS probe), and weights were recorded to track changes occurring after treatments were applied. Control muscles were cut into steaks after data were collected.

Mechanically tenderized muscles were passed twice through the TEND-R-RITE blade tenderizer (TR-2, Bettcher Industries, Inc., Birmingham, OH). This tenderizer consists of 294 blades (14 rows of 21 blades). Because of large and irregularly shaped muscles, they were folded to ensure the entire muscle received blade tenderization. The sides were folded into the middle so the muscle fit squarely on the tenderizer. After the first pass through the tenderizer, the muscles were turned over and rotated 90° to ensure even tenderization. After blade tenderization, muscle temperature, pH, and weight again were measured.

Muscles were injected with a water solution containing 6.5% sodium chloride (Morton Culinox 999 Food Grade Salt, Morton International, Inc, Chicago, IL), 3.5% sodium tripolyphosphate (Brifisol ® 512, BK Giulini Corp., Simi Valley, CA), 0.033% liquid papain (Liquipanol® T-100, Enzyme Development Corp., New York, NY) and the remainder potable water. Sodium tripolyphosphate, sodium chloride, and papain were added sequentially to the water, stirred using a highspeed mixer, and each ingredient was allowed to dissolve completely before adding the next. The solution (pH of 7.2) was injected into the muscle by a single pass through a commercial injector (Inject Star BI 72, Inject Star, Inc., Brookfield, CT). The injector was set at 11 for belt speed, and pressure of 4.5 out of meat and 3.5 when injecting the muscles. Again, muscle edges were folded to the middle to ensure consistent injection and create a uniform distribution throughout the muscle. Muscles injections ranged from 14% to 18% to reach a targeted pump of 12%. Muscles were over pumped to account for drainage time during data collection, further processing, and packaging. Final ingredient concentrations in steaks were estimated to be 0.65% to 0.78% sodium chloride, 0.35% to 0.42% sodium tripolyphosphate, and 0.0033% to 0.00396% papain.

After tenderization treatments, muscles were prepared for steak cutting. Initially, tapered ends were trimmed to obtain consistent thickness. Steaks were cut 2.54 cm thick from the dorsal to ventral end. Steaks then were tagged, weighed, and packaged. After packaging, steaks were frozen, and the fourth steak designated for WBS force analysis.

2.3 Warner-Bratzler Shear Force Analysis

Steaks assigned for WBS force were cooked to an internal temperature of 70°C using electric grills (Hamilton Beach Indoor/Outdoor Grill, Hamilton Beach/Proctor Silex, Inc., Southern Pines, NC) and monitored using Omega trendicators (Omega Engineering, Inc., Stamford, CT) fitted with a type-T thermocouple. Weights were recorded before and after cooking to determine cook loss. Steaks were covered, and allowed to cool overnight under refrigeration. The next day, steaks were allowed to equilibrate to room temperature before coring. Six 1.27 cm cores were removed from each steak, with cores taken parallel to the muscle fibers. Each core was sheared across the parallel fibers using a Universal Testing System Machine (United 5STM-500, Huntington Beach, CA), equipped with a 500 lb (226.8 kg) load cell and Warner-Bratzler shear attachment. The average of six cores was used to determine WBS force values.

2.4 Consumer Recruitment

Consumers were solicited for the in-home testing (n=175) through direct contact by Texas A&M University personnel (136 consumers completed the study). Consumers were given a box of three steaks, one from each treatment (control, blade tenderized, and injected), and were asked to prepare the steaks in their home as they would normally prepare a cut of beef. Consumers were instructed to prepare and evaluate one steak per meal for three meals. Furthermore, each consumer was asked to complete a demographics survey which is summarized in Table 1. Consumers were asked to identify their cooking method by referring to the definitions provided in the directions included in the packing box. Cooking method definitions were as follows: outdoor grill -- dry heat method, involving a grill to place meat on, over open flame or hot coals for cooking; indoor grill -- dry heat method, dry heat cookery, involves placing meat on a small electric grill;

Table 1
Demographic background of consumers

Age	**<20**	**20-29**	**30-39**	**40-49**	**50-59**	**>60**
% (n)	14.7% (20)	14.7% (20)	13.2% (18)	22.8% (31)	25% (34)	9.6% (13)
Income	**<$20,000**	**$20,000-39,000**	**$40,000-59,000**	**$60,000-79,000**	**$80,000-99,000**	**$100,000**
% (n)	24.4 (31)	15.7 (20)	15.7 (20)	15.0 (19)	15.0 (19)	14.2 (18)
Household size	**1**	**2**	**3**	**4**	**5**	**≥6**
% (n)	8.8 (12)	31.6 (43)	30.1 (41)	23.5 (32)	2.2 (3)	3.7 (5)
Work Status	**Not employed**		**Part-time**		**Full-time**	
% (n)	16.4 (22)		10.4 (14)		73.1 (98)	
Gender	**Male**			**Female**		
% (n)	50.7 (69)			49.3 (67)		
Nationality	**White**	**Hispanic**	**African American**	**Asian**	**Other**	
% (n)	82.8 (11)	16.4 (22)	0	0	0.7 (1)	
Beef Consumption*	**Never**	**1**	**2**	**3**	**≥4**	
% (n)	----	8.8 (12)	20.6 (28)	33.1 (45)	37.5 (51)	
In-home Beef Preparation*	**Never**	**1**	**2**	**3**	**≥4**	
% (n)	----	19.9 (27)	25.7 (35)	30.1 (41)	17.6 (24)	
Away From Home*	**Never**	**1**	**2**	**3**	**≥4**	
% (n)	----	44.1 (60)	25.7 (35)	17.6 (24)	12.5 (17)	
Primary Purchase	**Yourself**		**Spouse**		**Other**	
% (n)	52.9 (72)		29.4 (40)		17.6 (24)	
Meat Preparer	**Yourself**		**Spouse**		**Other**	
% (n)	55.6 (75)		28.9 (40)		15.6 (21)	
Preferred Cook Method	**Grill**	**Oven**	**BBQ**	**Panfry**	**Pan Broil**	**Braise/simmer**
% (n)	75.9 (101)	0.02 (3)	0.06 (8)	0.10 (13)	0.08 (11)	0.03 (4)

*Consumption and preparation were reported as the number of times consumed per week pan-broil -- dry heat cooking method, using medium to low heat in a skillet; pan-fry -- dry heat method, using medium heat in a skillet with a small amount of oil, sometimes called sautéing; stir-fry -- dry heat method, cooking slices of beef in a pan, usually with a small amount of oil, vegetables, and other ingredients, usually prepared in a Wok; broil -- dry heat method, includes placing on a broiling pan in oven, allowing juices to drip away; oven roasted, uncovered -- dry heat method, placing meat in a roasting pan or rack in the oven; braise and simmer -- moist heat method, created by adding water to the pan, usually preformed in dutch oven or large skillet with a lid; stew -- moist heat method, involves browning smaller pieces or cubes of meat and simmering in liquid over low-heat, covered (Bloch, 1977).

Approximate degree of doneness was determined by consumers using the National Cattlemen's Beef Association beef steak color guide (NCBA, 1998) provided in the box. Consumers were asked to evaluate steaks for overall-like, tenderness desirability, tenderness of cut, juiciness desirability, juiciness of cut, flavor desirability, and flavor intensity. These factors were rated using a 10-point scale (10 = extreme like, extremely tender, extremely juicy, extremely desirable, and extremely intense; 1=extreme dislike, extremely tough, extremely dry, extremely undesirable, and extremely bland). Consumers were asked to fill out evaluation forms immediately after each meal and mail responses back to Texas A&M University after testing the product. This study was approved by the Institutional Review Board at Texas A&M University regarding the use of human subjects, and informed consent was obtained from all participants.

2.5 Statistical Analysis

Analysis of variance was performed with SAS PROC GLM (SAS Institute, Cary, NC) and when significant differences occurred, means were separated using the p-diff option at $P < 0.05$. Initial models tested the main effects of tenderization treatment, degree of doneness, their interaction, and the treatment × degree of doneness interaction. Cooking methods were pooled into four categories including: grill (outdoor and indoor grilling), oven (broil and oven roasted, uncovered), skillet (pan-broil, pan-fry, and stir-fry), and moist cookery (braise and simmer and stew).

CHAPTER III

RESULTS AND DISCUSSION

3.1 Tenderization Treatments

Least squares means for consumer evaluations of steaks cooked on a grill are reported in Table 2. Ratings for tenderness were higher ($P < 0.05$) for injected steaks when compared to blade tenderized and control steaks. Juiciness ratings also were higher ($P < 0.05$) for injected steaks compared to control steaks. This follows the findings of Vote et al. (2000), Robbins et al. (2003), and McGee et al. (2003) who reported improved beef sensory tenderness and juiciness due to injection.

Table 3 reports the least squares means for treated steaks cooked in an oven. For tenderness, injected steaks received much higher ($P < 0.05$) ratings than the blade tenderized and control steaks. Tenderness score could be higher due to longer cooking times between 50° C and 80° C with oven cooking. Foegeding et al. (1986) and Caygill (1979) documented that plant enzymes are most active between these temperatures. Injected steaks also received higher ($P < 0.05$) juiciness ratings compared to blade tenderized steaks. This could be due to cooking loss in the blade tenderized steaks.

Table 2
Least-squares means ± SEM[a] for consumer evaluations of steaks cooked on the grill and subjected to blade tenderization or salt/phosphate/papain injection

	Treatment			
Attribute[b]	**Control**	**Blade**	**Injected**	**P > F**
n	75	75	75	
Overall like	7.0 ± 0.2	7.3 ± 0.2	6.8 ± 0.3	0.19
Tenderness Desirability	6.7 ± 0.3.	7.2 ± 0.3	6.9 ± 0.3	0.42
Tenderness	6.5 ± 0.3b	7.1 ± 0.2b	8.5 ± 0.3a	<0.0001
Juiciness Desirability	6.9 ± 0.2	6.9 ± 0.2	7.2 ± 0.2	0.31
Juiciness	6.6 ± 0.2b	6.9 ± 0.2ab	7.4 ± 0.2a	0.02
Flavor Desirability	7.0 ± 0.4	7.2 ± 0.2	7.1 ± 0.2	0.71
Flavor Intensity	6.9 ± 0.2	7.1 ± 0.2	6.8 ± 0.3	0.73

Means within the same row lacking a common letter (a, b) differ ($P < 0.05$).
[a]SEM is the standard error of the least-squares means.
[c]10=extreme like, extremely tender, extremely juicy, extremely desirable, and extremely intense; 1=extreme dislike, extremely tough, extremely dry, extremely undesirable, and extremely bland.

Table 3
Least-squares means ± SEM[a] for consumer evaluations of steaks cooked in the oven and subjected to blade tenderization or salt/phosphate/papain injection

	Treatment			
Attribute[b]	**Control**	**Blade**	**Injected**	***P* > F**
n	16	22	21	
Overall like	6.7 ± 0.4	7.2 ± 0.4	7.4 ± 0.4	0.42
Tenderness Desirability	6.5 ± 0.5	6.9 ± 0.4	7.6 ± 0.5	0.25
Tenderness	6.2 ± 0.4b	6.7 ± 0.4b	9.4 ± 0.4a	<0.0001
Juiciness Desirability	7.1 ± 0.4	6.7 ± 0.4	7.4 ± 0.4	0.45
Juiciness	7.2 ± 0.4ab	6.3 ± 0.4b	8.0 ± 0.4a	0.01
Flavor Desirability	7.3 ± 0.4	7.4 ± 0.3	7.6 ± 0.4	0.84
Flavor Intensity	7.1 ± 0.4	7.3 ± 0.3	7.0 ± 0.3	0.88

Means within the same row lacking a common letter (a, b) differ ($P < 0.05$).
[a]SEM is the standard error of the least-squares means.
[b]10=extreme like, extremely tender, extremely juicy, extremely desirable, and extremely intense; 1=extreme dislike, extremely tough, extremely dry, extremely undesirable, and extremely bland.

Table 4

Least-squares means ± SEM[a] for consumer evaluations of steaks cooked in a skillet and subjected to blade tenderization or salt/phosphate/papain injection

	Treatment			
Attribute[b]	**Control**	**Blade**	**Injected**	***P* > F**
n	31	27	27	
Overall like	7.6 ± 0.4	7.6 ± 0.4	7.7 ± 0.4	0.99
Tenderness Desirability	7.0 ± 0.4	7.1 ± 0.5	7.5 ± 0.5	0.65
Tenderness	7.4 ± 0.4b	7.2 ± 0.4b	8.7 ± 0.4a	0.03
Juiciness Desirability	7.5 ± 0.4	7.1 ± 0.4	8.0 ± 0.4	0.29
Juiciness	7.3 ± 0.4	6.9 ± 0.4	8.1 ± 04	0.11
Flavor Desirability	7.8 ± 0.4	7.0 ± 0.4	7.6 ± 0.4	0.35
Flavor Intensity	7.3 ± 0.4	7.2 ± 0.4	7.6 ± 0.4	0.78

Means within the same row lacking a common letter (a, b) differ ($P < 0.05$).

[a]SEM is the standard error of the least-squares means.

[c]10=extreme like, extremely tender, extremely juicy, extremely desirable, and extremely intense; 1=extreme dislike, extremely tough, extremely dry, extremely undesirable, and extremely bland.

Table 5
Least-squares means ± SEM[a] for consumer evaluations of steaks cooked using a moist heat method and subjected to blade tenderization or salt/phosphate/papain injection

Treatment				
Attribute[b]	**Control**	**Blade**	**Injected**	***P* > F**
n	7	5	5	
Overall like	7.8 ± 0.8	6.9 ± 1.0	7.8 ± 0.9	0.69
Tenderness Desirability	8.0 ± 0.8	7.3 ± 1.1	8.2 ± 0.9	0.77
Tenderness	6.7 ± 0.9	7.1 ± 1.2	8.4 ± 1.0	0.45
Juiciness Desirability	7.5 ± 0.7	7.3 ± 0.9	8.3 ± 0.8	0.60
Juiciness	7.0 ± 0.7	7.3 ± 0.9	8.1 ± 0.8	0.60
Flavor Desirability	6.4 ± 0.8	6.7 ± 1.1	8.2 ± 1.0	0.33
Flavor Intensity	6.0 ± 0.9	6.6 ± 1.1	7.8 ± 1.0	0.40

[a]SEM is the standard error of the least-squares means.
[b]10=extreme like, extremely tender, extremely juicy, extremely desirable, and extremely intense; 1=extreme dislike, extremely tough, extremely dry, extremely undesirable, and extremely bland.

Least squares means for consumer evaluation of steaks cooked in a skillet are reported in Table 4. Injected steaks received higher ($P < 0.05$) ratings for tenderness. This also follows the findings of Vote et al. (2000), Robbins et al. (2003), and McGee et al. (2003) who reported improved juiciness due to injection.

Least squares means for consumer evaluations of steaks cooked using a moist heat method are reported in Table 5. Values reported were not significantly different.

3.2 Degree of Doneness

Table 6 displays the least squares means for consumer evaluations of steaks cooked on the grill to varying degrees of doneness. None of the values reported were significantly different.

Least squares means for consumer evaluations of steaks cooked in the oven to varying degrees of doneness are reported in Table 7. Palatability attributes reported in this table were not significantly different.

Table 6
Least-squares means ± SEM[a] for consumer evaluations of steaks cooked on the grill[b] with varying degree of doneness

Degree of Doneness					
Attribute[c]	**Med Rare and Rare**	**Medium**	**Medium well**	**Well Done**	**P > F**
n	73	85	39	18	
Overall like	6.9 ± 0.2	6.8 ± 0.2	6.9 ± 0.3	7.6 ± 0.5	0.45
Tenderness Desirability	6.5 ± 0.3	6.8 ± 0.3	6.8 ± 0.4	7.7 ± 0.5	0.23
Tenderness	7.3 ± 0.2	7.4 ± 0.2	6.8 ± 0.3	7.9 ± 0.5	0.24
Juiciness Desirability	7.1 ± 0.2	7.0 ± 0.2	7.1 ± 0.3	6.9 ± 0.4	0.93
Juiciness	7.4 ± 0.2	7.0 ± 0.2	7.0 ± 0.3	6.5 ± 0.4	0.20
Flavor Desirability	6.8 ± 0.2	7.2 ± 0.2	7.1 ± 0.3	7.4 ± 0.4	0.62
Flavor Intensity	6.6 ± 0.2	6.8 ± 0.2	6.8 ± 0.3	7.6 ± 0.5	0.24

[a]SEM is the standard error of the least-squares means.
[b]Grill method includes outdoor and indoor grilling.
[c]10=extremely desirable, extremely tender, extremely juicy; 1= extremely undesirable, extremely tough, and extremely dry.

Table 7
Least-squares means ± SEM[a] for consumer evaluations of steaks cooked in the oven[b] with varying degree of doneness

Degree of Doneness					
Attribute[c]	**Med Rare and Rare**	**Medium**	**Medium well**	**Well Done**	***P* > F**
n	13	17	18	10	
Overall like	6.9 ± 0.4	7.9 ± 0.4	6.9 ± 0.4	6.7 ± 0.5	0.20
Tenderness Desirability	7.0 ± 0.6	8.0 ± 0.5	7.0 ± 0.5	6.1 ± 0.6	0.12
Tenderness	7.4 ± 0.5	7.9 ± 0.4	7.4 ± 0.4	7.0 ± 0.5	0.60
Juiciness Desirability	6.7 ± 0.5	7.7 ± 0.4	7.0 ± 0.4	7.0 ± 0.6	0.44
Juiciness	6.9 ± 0.4	7.4 ± 0.4	7.1 ± 0.4	7.3 ± 0.5	0.89
Flavor Desirability	7.1 ± 0.4	7.7 ± 0.4	7.4 ± 0.4	7.6 ± 0.5	0.71
Flavor Intensity	6.7 ± 0.4	7.5 ± 0.4	7.0 ± 0.4	7.3 ± 0.5	0.45

[a]SEM is the standard error of the least-squares means.
[b]Oven method includes broiling and oven-roasted, uncovered.
[c]10=extreme like, extremely tender, extremely juicy, extremely desirable, and extremely intense; 1=extreme dislike, extremely tough, extremely dry, extremely undesirable, and extremely bland.

Table 8 reports the least squares means for consumer evaluations of steaks cooked in a skillet to varying degrees of doneness. Significant difference was not found between values reported in this table.

Least squares means for consumer evaluations of steaks cooked using a moist heat method are reported in Table 9. Although no significant differences were found, these findings are similar to Kolle et al. (2004), which reported an increase in tenderness for all treatments when cooked using moist heat.

3.3 Treatment × Degree of Doneness

Table 10 reports the interaction between treatment and degree of doneness for overall like, juiciness desirability, flavor desirability, and flavor intensity. For overall like, injected steaks were rated higher (P <0.05) than all steaks except blade tenderized steaks cooked medium well and well done. Blade tenderized steaks, cooked well done, were also rated higher (P <0.05) than injected steaks cooked medium rare and medium, and control steaks cooked medium well and well done. These findings reveal that as you increase degree of doneness, you also increase overall like for injected and blade tenderized steaks.

Table 8
Least-squares means ± SEM[a] for consumer evaluations of steaks cooked in a skillet[b] with varying degree of doneness

Degree of Doneness					
Attribute[c]	**Med Rare and Rare**	**Medium**	**Medium well**	**Well Done**	***P* > F**
n	20	25	20	10	
Overall like	7.7 ± 0.4	6.9 ± 0.4	8.4 ± 0.4	7.7 ± 0.6	0.07
Tenderness Desirability	7.3 ± 0.5	6.9 ± 0.4	7.3 ± 0.5	7.3 ± 0.7	0.87
Tenderness	7.8 ± 0.4	7.3 ± 0.4	7.5 ± 0.4	8.4 ± 0.6	0.43
Juiciness Desirability	7.7 ± 0.4	7.2 ± 0.4	7.8 ± 0.4	7.4 ± 0.6	0.70
Juiciness	8.0 ± 0.4	7.2 ± 0.4	7.6 ± 0.4	6.9 ± 0.6	0.34
Flavor Desirability	7.6 ± 0.4	7.4 ± 0.4	7.5 ± 0.4	7.5 ± 0.6	0.98
Flavor Intensity	7.7 ± 0.5	7.0 ± 0.4	7.3 ± 0.5	7.5 ± 0.6	0.77

Means within the same row lacking a common letter (a, b) differ ($P < 0.05$).
[a]SEM is the standard error of the least-squares means.
[b]Skillet method includes pan-broil, pan-fry, and stir-fry.
[c]10=extreme like, extremely tender, extremely juicy, extremely desirable, and extremely intense; 1=extreme dislike, extremely tough, extremely dry, extremely undesirable, and extremely bland.

Table 9
Least-squares means ± SEM[a] for consumer evaluations of steaks cooked using moist heat cookery[b] with varying degree of doneness

Degree of Doneness				
Attribute[c]	**Medium and below**	**Medium well**	**Well Done**	***P* > F**
n	2	10	5	
Overall like	7.2 ± 1.4	7.0 ± 0.6	8.3 ± 0.9	0.49
Tenderness Desirability	8.2 ± 1.4	6.8 ± 0.6	8.6 ± 0.9	0.27
Tenderness	7.8 ± 1.6	7.0 ± 0.7	7.3 ± 1.0	0.89
Juiciness Desirability	7.3 ± 1.2	7.4 ± 0.5	8.3 ± 0.8	0.64
Juiciness	7.4 ± 1.3	7.3 ± 0.6	7.6 ± 0.8	0.97
Flavor Desirability	5.8 ± 1.5	7.1 ± 0.6	8.3 ± 1.0	0.36
Flavor Intensity	5.9 ± 1.6	6.8 ± 0.7	7.7 ± 1.0	0.58

[a]SEM is the standard error of the least-squares means.
[b]Moist heat cooking includes braise and simmer and stewing.
[c]10=extreme like, extremely tender, extremely juicy, extremely desirable, and extremely intense; 1=extreme dislike, extremely tough, extremely dry, extremely undesirable, and extremely bland.

Table 10

Least-squares means ± SEM[a] for consumer evaluations for treatment × degree of doneness for steaks cooked on the grill

	Palatability Attributes			
	Overall Like	**Juiciness Desirability**	**Flavor Desirability**	**Flavor Intensity**
Control				
Medium rare	7.2 ± 0.4bc	7.2 ± 0.4ab	7.0 ± 0.4bcd	6.7 ± 0.4bc
Medium	7.1 ± 0.4bc	6.9 ± 0.3b	7.2 ± 0.3abc	7.1 ± 0.3bc
Medium well	6.4 ± 0.6c	6.7 ± 0.5bc	6.6 ± 0.6bcd	6.2 ± 0.6c
Well done	6.0 ± 0.8c	5.2 ± 0.7c	5.5 ± 0.8d	6.0 ± 0.8c
Blade Tenderized				
Medium rare	7.0 ± 0.4bc	7.2 ± 0.4ab	7.1 ± 0.4abcd	6.7 ± 0.4bc
Medium	7.1 ± 0.4bc	6.6 ± 0.3bc	7.1 ± 0.4abcd	6.9 ± 0.4bc
Medium well	7.2 ± 0.5abc	7.3 ± 0.5ab	7.1 ± 0.5abcd	6.8 ± 0.5bc
Well done	8.1 ± 0.7ab	7.0 ± 0.6ab	8.0 ± 0.7ab	8.1 ± 0.7ab
Injected				
Medium rare	6.3 ± 0.4c	6.9 ± 0.4b	6.4 ± 0.4cd	6.4 ± 0.4c
Medium	6.2 ± 0.4c	7.4 ± 0.3ab	7.1 ± 0.4abcd	6.2 ± 0.4c
Medium well	7.1 ± 0.5bc	7.3 ± 0.4ab	7.3 ± 0.5abc	7.1 ± 0.5bc
Well done	9.3 ± 0.9a	9.0 ± 0.9a	9.0 ± 0.9a	9.3 ± 0.9a
***P* > F**	0.0460	0.0394	0.0490	0.0500

Means within the same column lacking a common letter (a-d) differ ($P < 0.05$).

[a]SEM is the standard error of the least-squares means.

[b]10=extreme like, extremely desirable, and extremely intense; 1=extreme dislike, extremely undesirable, and extremely bland.

For juiciness desirability, injected steaks cooked well done ranked higher (P<0.05) than injected steaks cooked medium rare, blade tenderized steaks cooked medium, and control steaks cooked to a medium degree of doneness and higher. As expected, cooking control steaks to a higher degree of doneness decreased (P <0.05) the juiciness desirability, opposed to injected steaks that increased (P <0.05) in scores with increased degree of doneness. Within the control group there was a significant (P <0.05) increase in juiciness desirability from steaks cooked well done, to steaks cooked medium rare.

Injected steaks cooked well done, displayed higher (P <0.05) flavor desirability ratings than injected steaks cooked medium rare, and control steaks cooked medium rare, medium well, and well done. Within the control treatment, steaks cooked to a medium degree of doneness received higher scores than steaks cooked well done.

For flavor intensity, injected steaks cooked well done received significantly higher (P <0.05) ratings over all steaks except blade tenderized steaks cooked well done. Blade tenderized steaks cooked well done, also rated higher (P <0.05) than injected steaks cooked medium and lower, and control steaks cooked to medium well and higher.

3.4 Warner-Bratzler Shear Force

WBS force values were compared and means are shown in Table 11. Injected steaks had the lowest (P < 0.05) WBS values compared to control and blade tenderized. This was similar to the findings of Kolle et al. (2004), Mueller et al. (2006), and Baublits et al. (2006).

Table 11
Least-squares means ± SEM[a] of WBS values (N)

Treatment			
Control	**Blade**	**Injected**	***P* > F**
19.9 ± 2.7b	18.4 ± 3.0b	13.1 ± 3.5a	<0.0001

Means within the same row lacking a common letter (a, b) differ ($P < 0.05$).
[a]SEM is the standard error of the least-squares means.

CHAPTER IV

SUMMARY AND CONCLUSIONS

Based on objective mechanical tests, the *M. Serratus ventralis* proved to be adequate for use as a retail steak. When tested for tenderness, steaks from all treatments fit into the “very tender” category as established by Belew et al. (2003). When subjective comparisons were made between treatments, all treatments appeared to be adequate for the palatability. Of the treatment methods used, the injected steaks not only seemed to rank the highest, but also tended to increase in ratings as the degree of doneness increased. Therefore if retailers or processors used injection as the chosen method of tenderization, it would be beneficial to advise consumers that cooking steaks to well done should produce the best eating experience. For retailers and processors who choose blade tenderization, variability in degree of doneness would not necessarily result in any change in palatability attributes. Furthermore, if steaks were not tenderized consumers should cook to lower degrees of doneness to avoid undesirably juiciness.

Even though injected steaks did have consistently high palatability ratings when using the grill, other cooking methods can be used. The consumer needs to be aware that product injected with papain could become “too tender” or “mushy”, if cooked at high temperatures for long periods of time. For example, injected steaks could have adverse effects if used for stewing. Retailers and processors should use these recommendations to better merchandise the *M. Serratus ventralis* as a high quality, modestly priced steak from the chuck.

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VITA

Name: Jason Lee Bagley

Hometown: San Antonio, Texas

Education: Texas A&M University
B.S., Animal Science
May 2003

Texas A&M University
M.S., Animal Science (Meat Science)
December 2006

Department Address: 2471 TAMU KLCT 348
College Station, TX 77843